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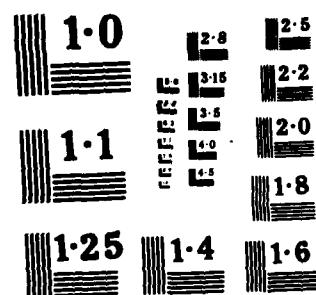
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Aero Propulsion Technical Memorandum 430

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G.F. Forsyth

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AERO PROPULSION TECHNICAL MEMORANDUM 430

COMPARISON OF AIRBORNE DATA
ACQUISITION SYSTEMS AT ARL

by

G.F.FORSYTH

SUMMARY

Since requirements for airborne data collection vary widely, there are a number of different types of acquisition systems in use at ARL. Some of these systems are very old and some have very specialized applications. A comparison has been performed which attempts to identify the major characteristics of each of these systems.

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1. INTRODUCTION

During formulation of plans to raise contracts to implement a new data acquisition arrangement to suit aircraft engines and other propulsion components, it became necessary to evaluate other systems which might be available for the same or similar tasks. Accordingly details have been collected on all the various airborne data acquisition systems which may be considered for use at ARL.

Later sections of this paper will compare the major capabilities of the various airborne data acquisition systems currently available at ARL and of some systems which have recently become available from industry. The systems have been considered in alphabetical order. First, however, the problem of airborne data acquisition will be defined in general terms to provide a basis for such comparison.

2. CLASSES OF AIRBORNE DATA PROBLEMS

Three distinct classes of airborne data problems are likely to arise at ARL. These are:

1. Prototype flight tests: Such tests are distinguished by the need for many data channels, diverse data types, wide aircraft operating ranges (often venturing up to or beyond the aircraft's normal limits) but the tests need to be conducted only over an extremely restricted geographical area (often within the confines of a particular airfield) and only for a limited period. For these reasons, air-to-ground telemetry is usually used in such cases and none of the systems considered here is regarded as suitable for this application.
2. Extended condition monitoring: These tests involve fewer channels of more definite data types over extended periods of normal aircraft operation. Since such operation may extend over a wide geographical area, the use of telemetry is not practical and any system installed should cause minimum restriction to aircraft operation. In many cases, this means that fully automatic operation of the system is required. Each of the systems considered below will be evaluated for this class of usage.
3. Short term ad-hoc trials: These tests typically involve only a restricted number of channels and limited amount of data. The main problem here is often uncertainty in test procedure which makes easy programming of the system a distinct advantage. The ability to examine the data in-flight (a "quick-look" facility) is often important in such trials as is the ability to perform accurate calibration of the installed equipment quickly and simply.

Since the aircraft is often removed from normal service for the trial period, the data acquisition system may restrict some uses of the aircraft and often need not operate unattended in this application. Each of the systems considered below will also be evaluated for this class of usage.

Keywords: flight testing
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3. TYPES OF AIRBORNE DATA SOURCES

The type of data source involved can strongly influence the choice of data collection method and the amount of data storage required. Typically, data sources may be:

1. Low level voltages, such as from strain gauge bridges;
2. Low level voltages requiring special compensation, such as from thermocouples;
3. High level voltages, such as from pressure transducers, and from the outputs of amplifiers used to pre-condition low level measurands;
4. Phase dependent AC signals such as from synchros, resolvers and LVDTs which normally need special detectors;
5. Audio frequency (e.g. 2000 to 10000 Hz) pulses trains such as produced by turbine engine speed indicators (these often are also low level needing special amplification) for which the pulse repetition rate/interval provides a measurement of the required parameter;
6. Low frequency (e.g. 50 to 1000 Hz) pulses trains such as produced by fuel flow meters for which the pulse repetition rate/interval provides a measurement of the required parameter;
7. Discrete digital signals such as produced by switch closures, limit microswitches etc.; and
8. Variants and combinations of the above.

Different applications will require a different number of each of these input types. A long term structural test, for example, may require a large number of low level analog voltage inputs, a few synchro inputs to read standard aircraft instruments and very few other inputs, while a long term engine performance test may require fewer channels but some of each of the types mentioned above. The systems examined in the next section will be assessed particularly on the range and number of their data channels.

4. CHARACTERISTICS OF THE VARIOUS ACQUISITION SYSTEMS AVAILABLE

The major capabilities and limitations of the various airborne data acquisition systems available at ARL are examined in Sections 4.1 to 4.7 and comments in respect of other commercial systems not available at ARL are made in Section 4.8.

4.1 AFTRAS

The Airborne Flight Test Recording & Analysis System (AFTRAS) was developed at ARL by Structures Division in the late 1960's and early 1970's. The design was revised in the late 1970's for RAAF Aircraft Research and Development Unit (ARDU). DRCS manufactured the revised design for the RAAF. The equipment is designed to aircraft military specification and uses a commercial military-rated 7-track tape deck.

Inside the tape deck housing, provision has been made for up to 96 analog channels (± 5 V) and up to 80 input filters (1 to 100 Hz, typically 40 Hz). Signal conditioning must be external and external digital and analog channels may be added up to a total of 255 channels. The data rate is set according to the tape speed and may be as high as 24,000 readings per second. The tape capacity is 10 million readings. Data are recorded as 12-bit words.

The unit is approximately 28 kg in mass and 26 litres in volume.

Important capabilities of this unit are its large storage capacity, rapid data rate and high channel capacity. Problems arise because the tape deck is of 1960's vintage which is now obsolete and because of the lack of provision for other input types such as synchros, pulse-rates etc. It would appear that this unit is oriented towards major structural trials. Extensive external signal conditioning is needed for most applications.

4.2 AFDAS

This unit is not presently available at ARL but is used widely in Australia for particular types of long term structural monitoring. It is included here since it is a possible replacement for the AFTRAS unit when limited numbers of input channels are required.

The Aircraft Fatigue Data Analysis System is a commercial product of British Aerospace Australia Limited. It is an improved version of a Strain Range-Pair Fatigue Counter developed by Structures Division, ARL. Up to 12 strain gauge or accelerometer transducers can be directly connected to the unit, with adjustable gain to suit each channel. Input filters limit response to 30 Hz. Incoming data are processed in real-time to detect input events (such as a particular level on a specified input) which are counted on 120 event counters. 64 kilobytes of battery backed CMOS memory maintain the AFDAS data until they are transmitted to a dedicated data extraction unit. AFDAS could be reprogrammed to perform other tasks but the fundamental design of the unit is aimed at the collection of in-flight structural fatigue data.

4.3 DAVALL 1050

The Davall Flight Data Recorder type 1050 is a very early unit similar in many respects to the ARL designed "Black Box" aircraft crash recorder. It has a single analog recording channel (using stainless steel wire) and hence requires an external multiplexer for multichannel operation. It has

a recording capacity of 200 flight hours.

The unit is rated to extreme environments such as accelerations up to 100g and temperatures up to 800 Celsius for 15 minutes. The wire used to record the data is contained in a removable cassette and is of length 80 km. It has a mass of 12 kg and a size of 19 litres. This unit is of great historical interest and is not considered to be of any practical value except in cases requiring extreme environmental capability.

4.4 EULMU

The Plessey Engine Usage Life Measurement Unit (EULMU) is a commercial unit purchased by Aero Propulsion Division during 1982. It is a full military-rated data acquisition system designed specifically for use with engines, although capable of many other uses.

EULMU forms the data acquisition element of the Plessey Engine Usage Life Monitoring System (EULMS) which also includes a Visual Digital Display Unit (VDDU) and a Quick Access Recorder (QAR). The most significant application of EULMS in recent years has been for digital engine controls evaluation for the Pegasus engine in the AV-8B Harrier. In this application more than 50 parameters were recorded at sampling rates ranging from 32 to 512 readings per second. More recently EULMS has been used in the UK in studies of the health and life usage of helicopter rotating machinery, a subject of extreme interest at this time. Plessey also manufactures a variant of EULMS referred to as Structural Usage Monitoring System (SUMS) for studies on structural components. RAAF purchased two sets of EULMS for use in low cycle fatigue studies of the TF-30 engine in F111 aircraft but later decided not to proceed with the use of EULMS in this application because of the high cost of the required industrial support for this work coupled with reduced need following a redesign of critical engine components by the manufacturer. RAAF is considering EULMS for use in its C130/P3 aircraft.

EULMU was considered by Aero Propulsion Division to be that part of EULMS which would be of most benefit in its propulsion studies. The VDDU was considered a little too specialized and there were some reservations about the environmental specification of the QAR. These latter units were not purchased by Aero Propulsion Division. However EULMU needs external data storage and an external control unit. A military-rated data storage system was also purchased to form a system with the EULMU. This is the Sundstrand SETS-1 tape system and its interface unit. An external control unit has been designed at ARL and manufactured by industry. This unit is called the System Integration and Display (SID). It has been manufactured in such a way that certification of the overall system is a possibility. The SID unit also allows a certain degree of in-flight checking of data by allowing a chosen channel to be continuously displayed.

The EULMU can accommodate a wide range of input types, including the outputs from digital signal lines, pulse rate sensors, synchro-resolvers of several types, thermocouples, RTDs and pressure transducers.

The EULMU unit itself occupies approximately 5.6 litres, the SETS Interface and Tape Recorder unit occupy 1.2 and 1.4 litres respectively and the SID unit 0.7 litres. The masses of the units are 4.4 kg for the EULMU,

1.5 kg for the SETS interface, 1.5 for the SETS Tape Recorder and 0.6 kg for the SID.

This system is optimized for longer term data collection on aircraft engines and other aircraft components. A request for TSS funding to obtain software systems to simplify the use of this system (which would allow use for some types of trials work) has been delayed until at least 1986/87.

4.5 MADAR

The Microprocessor Airborne Data Acquisition & Replay (MADAR) unit was designed at ARL by Aerodynamics Division in the late 1970's and early 1980's. It has 13 analog voltage channels, each of range ± 5 V, three inputs for 3-phase synchro-resolvers, each 11.8 volt per phase with 26 volt 400 Hz reference, and two 16-bit digital data ports. Most of the analog channels have filters of 0.86 or 5 Hz cut-off and data are read from selected channels at rates of 5 to 20 readings per second.

Analog data are converted to 12-bit digital data with 4-bit channel address. All information is stored as 16-bit words. Data are recorded on digital cassette tape contained within the unit. The storage capacity is 370 data blocks of 256 data words.

The total mass of the unit (including 115V 50-400Hz mains transformer) is 33 kg, the volume is approximately 66 litres and the unit is not rated to military standards.

The MADAR unit itself is used as the ground replay unit as well as providing an in-flight "quick-look" facility. It connects to other computers via standard serial lines.

It is considered that the MADAR is optimized for single-flight ("trials") work rather than long term tests such as for engine health monitoring. This is evidenced by the emphasis on ease of programming compared to the lack of any pulse rate inputs, the low data storage capacity, the large size of the unit and its non-compliance with military standards.

4.6 SR-DC450

The Structural Recorder using DC450 tape cartridges was designed at ARL under the control of Structures Division to help test the British Aerospace AFDAS system. It fits in an 1/2 ATR case and includes a DC450 cartridge tape drive, 16 strain-gauge amplifier inputs and a digital filter. It records up to 2.5 million 12-bit data words at rates up to 480 readings per second. It has a mass of approximately 8 kg and a volume of approximately 8 litres. It is considered useful only for limited structural tests.

4.7 16CAD

Two versions of this late 1960's ARL-designed system are currently supported. The first version has 16-channel capacity and was developed under the control of Aero Propulsion Division and was an extension of an earlier VGH recorder developed by Structures Division. The second version is an extension of the first unit with double the number of input cards. This later version supports approximately 30 channels. Both systems use tri-tone recording on standard audio cassettes. It is not processor-based but uses a sequencer to read channels selected by a PROM. Input channels are available for high level analog, pulse rate and synchro data types and data are basically recorded as 8-bit digital bytes. However, a 10-bit adaptor is available which allows the "extra" 2 bits from 4 channels to be recorded on a spare channel. Data recording rate is 16 channels per second. Since an analog cassette tape is used, total capacity is about 30 minutes per side of the cassette. This amounts to approximately 25,000 readings.

Since some hardware customization is required to select configurations for this unit, it is not considered ideal for short term "trials". It has been used for longer term monitoring jobs but is considered restricted in the number of channels available and data storage capacity. The author would not recommend its use in new applications.

4.8 OTHER COMMERCIAL UNITS

Firms such as Plessey and Dornier manufacture commercial systems which are suitable for some of the uses required at ARL. However these systems are very expensive and tend to be very specialized. The Plessey systems largely comprise special versions of the EULMU system described above. The Dornier system (MUDAS) is very comprehensive but significantly more expensive. It uses the same SETS-1 recorder as the ARL modified EULMU. Other firms such as ROLM and Norden make airborne processors which may be connected to appropriate interface cards to produce suitable systems. Such systems tend to be too expensive when supplied as single systems.

5. CONCLUSION

Important capabilities of the systems examined above are compared in the following table. Some of the systems have more than one possible configuration (e.g. 16 and 30 channel versions of 16CAD). Tabulated results are for the highest performance version in each case. Views expressed concerning the possible uses and usefulness of each of the systems are the author's own.

Despite the wide range of systems apparently available, only the MADAR unit is considered suitable as presently configured for "trials" work although it is considered possible to upgrade EULMU to this capability. For long term "monitor" work, the EULMU is clearly superior if a wide range of inputs is required. AFTRAS is obviously suitable only for structural work and is probably approaching the end of a long life. The 16CAD would not be considered for new applications. For these reasons, the

author considers that Aero Propulsion Division plans to proceed with implementation of the EULMU are fully justified. It may well be that a variant on EULMU may be a suitable replacement for AFTRAS and the proposed addition of menu selection software to EULMU will allow it to do some "trials" work as well.

Table 1.
Comparison of Claimed Features

FEATURE	AFTRAS	AFDAS	EULMU	MADAR	SR/DC450	16CAD
LOW LEVEL	0	12	0	0	16	0
5V ANALOG	96	0	40*	13	0	20
SYNCHRO	0	0	16*	3	0	2
PULSE RATE	0	0	16	0	0	5
DIGITAL	159	0	20	32	0	0
RESOLUTION (BIT)	12	8	12	12	12	8 - 10
DATA RATE (MAX)	24K	30	256	20	480	16
STORAGE LIMIT+	10M	64K	2M	90K	2.5M	25K
MASS (kg)	28	4.5	8	33	8	12
VOLUME (l)	26	5.8	9	66	8	7
PIECES	1	1	4	1	1	1
MILITARY RATING	YES	YES	YES	NO	POS	POS
PROGRAMMABLE	PART	PART	YES	YES	PART	PART
QUICK LOOK FAC.	NO	NO	SOME	YES	NO	NO
SUIT "TRIALS"	NO	NO	MAYBE	YES	NO	NO
SUIT "MONITOR"	YES	NO	YES	NO	YES	MAYBE

TABLE NOTES.

* The number of analog EULMU channels (5V full scale) possible is reduced from 40 by 2 channels for every synchro channel used. The maximum data rate on EULMU synchro channels is 64 readings per second.

+ The storage available has been expressed in equivalent number of readings.

Low Level inputs may also be used for 5V inputs on AFDAS and SR/DC450.

ABBREVIATIONS -- On the above table, POS indicates that this feature is possible at some later date, PART indicates that this feature applies to only portion of the system operation and MAYBE indicates that while not strictly suitable for this application limited use may be practical.

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